DIFFRACTIVE VECTOR MESON PRODUCTION IN A UNIFIED κ-FACTORIZATION APPROACH

I.P. IVANOV, N.N. NIKOLAEV

IKP (Theorie) Forschungszentrum Jülich, Germany
E-mails: i.ivanov@fz-juelich.de, n.nikolaev@fz-juelich.de

In the framework of the κ-factorization approach and on the basis of recently determined DGSF, we calculated the production rates of ground and excited ($2S$ and D wave) states of vector mesons and investigated their various kinematical and spin dependencies. We also addressed the issue of S/D wave mixing in quarkonia.

1 The vector meson production amplitude

The general amplitude of diffractive production of vector meson V is well known: the basic quantity is the cross section of $q\bar{q}$ color dipole interaction with the proton, which is convoluted with the initial photon and final vector meson wave function (WF). Algebraically, the amplitude in the diagrammatically straightforward κ-factorization approach reads:

$$\mathcal{A}(x, Q^2, \vec{\Delta}) = is \frac{c_V \sqrt{4\pi\alpha_{em}}}{4\pi^2} \int_0^1 \frac{dz}{z(1-z)} \int d^2\vec{k}\psi(z,\vec{k})$$
$$\cdot \int \frac{d^2\vec{\kappa}}{\vec{\kappa}^4} \alpha_S(q^2) \left(1 + i\frac{\pi}{2}\frac{\partial}{\partial \log x}\right) \mathcal{F}(x, \vec{\kappa}, \vec{\Delta}) \cdot I(\gamma^* \to V)$$

This expression contains two pieces non-calculable within pQCD: the vector meson WF $\psi(z, \vec{k})$ and the differential gluon structure function (DGSF) $\mathcal{F}(x, \vec{\kappa}, \vec{\Delta})$. The principal novelty of this work is that DGSF is now under control. The off-forward DGSF $\mathcal{F}(x, \vec{\kappa}, \vec{\Delta})$ can be linked to the forward DGSF, which has been recently determined from experimental data on F_{2p} in the whole Q^2 domain [1]. This dramatically reduces the level of ambiguity in diffractive vector meson production calculations, leaving us only with one unknown quantity — the vector meson WF.

The vector meson WF involves two components: the spinorial structure of the $q\bar{q}V$ vertex and the radial WF $\psi(\mathbf{k}^2)$. In our work we consistently used the spinorial structures corresponding to $q\bar{q}$ pair sitting in pure S or D wave state [2]. This allows us to address production of both ground ($1S$) and excited ($2S$, D wave) vector meson states as well as S/D wave mixed states. For the radial WF we chose a simple soft WF Ansatz (i.e. without specific large-$\mathbf{k}$, or short distance, enhancement) with parameters adjusted to match the vector meson $V \to e^+e^-$ decay width.

2 Production of ground states

We calculated the production rates of ground ($\equiv 1S$) state vector mesons $\rho^0, J/\psi, \Upsilon(1S)$ and compared predictions with the experimental data. We observed good agreement in a broad Q^2 range and confirmed the scanning phenomenon (the cross sections of different vector mesons, corrected by the flavor factor, are almost the same when expressed in terms of the scaling variable $Q^2 + m_V^2$). We also observed that the predicted energy dependence and $|t|$-dependence are the same as inferred from the experiment (this is best illustrated by plotting the effective intercepts and effective slopes as functions of the same scaling variable).

We also compared cross sections σ_L and σ_T in the ρ^0 meson case with experiment. We found good description of σ_L but observed a strong systematic departure of our predictions for σ_T from experimental data in the high-Q^2 region: our curves go substantially lower than the data. The disagreement between predicted σ_L/σ_T ratio and the data is, of course, the consequence of this σ_T puzzle. Since the gluon density is under control, such a deviation can only be attributed to the WF Ansatz. In other words, it seems that the soft WF does not exhaust the whole physics at short distances. Another possible solution will be given later.

Since in our approach we took into account all helicity amplitudes, both s-channel helicity conserving and violating ones, we have predictions for the whole set of density matrix elements. We observed that our predictions for ρ and ω mesons are in agreement with experiment.

3 Production of excited states

We calculated the cross section of $2S$ and D wave vector meson production in the case of ρ-system and charmonium as functions of Q^2. These cross sections were found suppressed in comparison with $1S$ states, the magnitude of suppression following remarkably different Q^2 behavior for $2S$ and D wave states. This difference is due to distinct mechanisms of suppression: in the case of $2S$ state this is the well-known node effect, while for D wave state it comes from vanishing radial WF at origin.

For illustrative purposes we also calculated ratios σ_L/σ_T and density matrices for production of $2S$ and D wave states in the ρ system. The prominent features of σ_L/σ_T (Fig.1) (non-monotonous Q^2 behavior for $2S$ state and strong, about one order of magnitude, suppression for D wave state) should serve as very clear experimental indicators in extracting excited vector meson signal. Also, many of density matrix elements, especially helicity violating ones, are very distinct in the case of $1S/2S/D$ wave states.
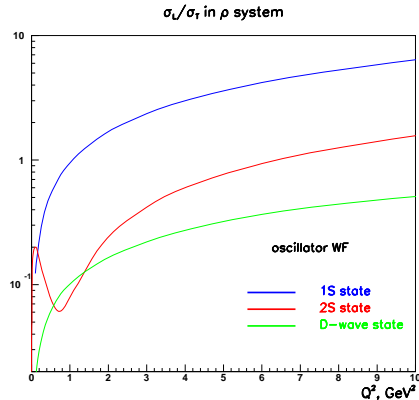
Figure 1: Ratio σ_L/σ_T for $1S/2S/D$ states in the ρ-system

4 S/D wave mixing

It is known that tensor forces, which naturally appear in quark potential models, lead to S/D wave mixing of $q\bar{q}$ states. This mixing can be quite strong, which is indicated by the e^+e^- decay width of D-wave candidate in the charmonium spectrum $\psi(3770)$. As an example of effects that S/D mixing can lead to we calculated ratio σ_L/σ_T for ρ meson in the presence of mixing. We saw that the above mentioned σ_L/σ_T puzzle can be, in principle, eliminated at the expense of strong S/D wave mixing. Further work is necessary to find out if this is the case.

References

1. I.P. Ivanov, N.N. Nikolaev, E-print: hep-ph/0004206 (2000); I.P. Ivanov, *"Anatomy Of The Proton Structure Functions In κ-Factorization"*, these proceedings.
2. I.P. Ivanov, N.N. Nikolaev, *JETF Lett.* **69** (1999) 294; I.P. Ivanov, MSc thesis, E-print: hep-ph/9909394 (1999).